National Aeronautics and Space Administration

# The Lighter Side of TPF – evaluating scientific gain from different architectures

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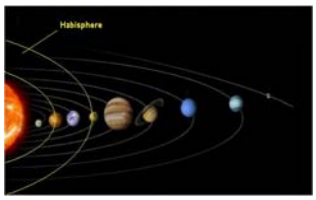
## Project Objective

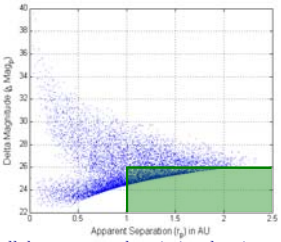
- To determine the scientific gain from large and small mission concepts
- To provide a measuring stick by which different missions may be judged.
- To provide the framework for developing a Design Reference Mission.

## Project Description

### Completeness



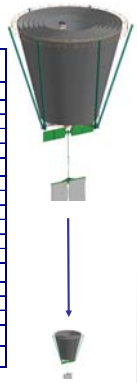

- Each star has a habitable zone which is determined by the stellar luminosity and mass
- In order to define this habisphere we populate the habitable zone of the given star with 10,000 planets in random orbits with eccentricities from 0 to 0.1
- Completeness is the fraction of planets that we are able to observe in a single stellar visit (green box).




- Total accumulated completeness is the sum of all the completeness values for all the stars over the mission duration.
- For ηearth=1, the total accumulated completeness is equal to the expected number of detections.

### Terminology

| | Type | IWA (l/Dmax) | Min. Revisit Time | Overhead | Primary Mirror |
|---|---|---|---|---|---|
| Large-class Mission (> $2B) | | | | | |
| TPF-I | Classic-X Array | 2.5 | 2 wk | 70% eff | 4 @ 4 m plus beam combiner spacecraft |
| TPF-C | Flight Baseline - 1 | 4 | 3 wk | 2 hrs | 8 m x 3.5 m |
| TPF-C | Flight Baseline - 1 with Pupil Mapping (PIAA) | 4 | 3 wk | 2 hrs | 8 m x 3.5 m |
| TPF-O | External Occulter (Dual) | ~2.5 | 1 / 3 wk | 6 / 20 days | 4m telescope + 25m and 50m occulter |
| Mid-class Mission (< $2B) | | | | | |
| TPF-I | Emma-X Array | 2.5 | 2 wk | 70 % eff | 4 @ 2 m plus beam combiner spacecraft |
| TPF-C | Shaped Pupil. BL Mask or Visible Nuller | 3.5 | 3 wk | 2 hrs | 4 m |
| TPF-C | Pupil Mapping (PIAA) | 3.5 | 3 wk | 2 hrs | 4 m |
| TPF-C | Pupil Mapping (PIAA) | 2.5 | 3 wk | 2 hrs | 4 m, aggressive IWA |
| TFF-O | External Occulter (Large) | ~2.5 | 3 wk | 20 days | 4 m telescope + 50 m occulter @ 72000 km |
| TFF-O | External Occulter (Small) | ~2.5 | 1 wk | 6 days | 4 m telescope + 25 m occulter @ 30000 km |
| Small-class Mission (< $1B) | | | | | |
| TPF-C | Shaped Pupil, BL Mask or Visible Nuller | 3.5 | 3 wk | 2 hrs | 2.5 m |
| TPF-C | Pupil Mapping (PIAA) | 3.5 | 3 wk | 2 hrs | 2.5 m |
| TPF-C | Pupil Mapping (PIAA) | 2.5 | 3 wk | 2 hrs | 2.5 m, aggressive IWA |
| Aggressively small-class Mission (~ $600M) | | | | | |
| TPF-C | Pupil Mapping (PIAA) | 2.5 | 3 wk | 2 hrs | 1.5 m, aggressive IWA |



### Small Mission Planet Definitions

Earth-twin
- $R_p$ = 1
- HZ = 1AU or 1.5 AU
- Albedo = 0.2

Super-Earth
- $R_p$ = 2
- HZ = 1AU or 1.5 AU
- Albedo = 0.2

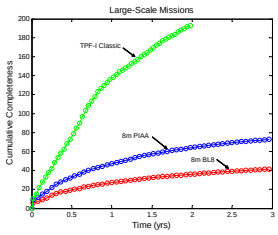
Super-Earth w/ gas envelope
- $R_p$ = 4.2
- HZ = 1AU or 1.5 AU
- Albedo = 0.44

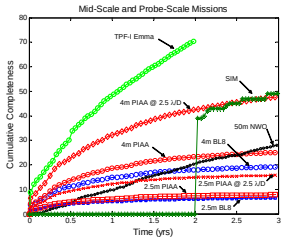
Jupiter-twin
- $R_p$ = 11
- HZ = 5 AU
- Albedo = 0.44

Saturn-twin
- $R_p$ = 9.1
- HZ = 9 AU
- Albedo = 0.47

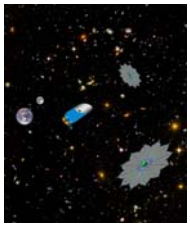
## Recent Results

### Large and Mid-Scale Mission Results



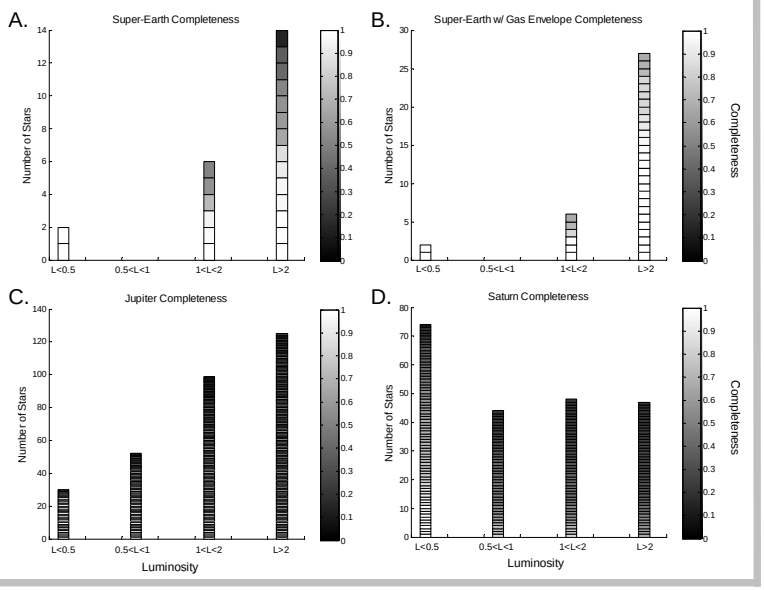




### Single and Dual Occulter Results



| Occulter Scenario | $\eta_{Jupiter}$ | Targets | Completeness |
|---|---|---|---|
| Small | N/A | 60 | 23.46 |
| Large | N/A | 63 | 28.39 |
| Dual | 0.1 | 2 | 1.25 |
| Dual | 0.3 | 17 | 6.30 |
| Dual | 0.5 | 28 | 10.73 |
| Dual | 0.7 | 39 | 14.46 |
| Dual | 1.0 | 50 | 17.38 |

### Aggressively Small-Class Mission Results




## Benefits to NASA and JPL

The current work provides a baseline to judge the scientific benefit provided by different mask designs, different size missions and different scientific objectives.

## Publications

Hunyadi, Shaklan and Brown, "The lighter side of TPF-C – evaluating the scientific gain from smaller mission concepts," SPIE 26-30 August 2007
Hunyadi, Shaklan and Lo, "The darker side of TPF – detecting and characterizing extra-solar Earth-like planets with one or two external occulters," SPIE 26-30 August 2007
Brown, R. A. 2004, ApJ, 607, 1003
Brown, R. "Single-Visit Photometric and Obscurational Completeness," ApJ 624, 1010, (2005)